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HYDROCARBON LEAKAGE FROM PRESSURE RELIEF VALVES

Bernard J. Steigerwald

Joint District, Federal and State Project for the Evaluation of Refinery Emissions

May 1957

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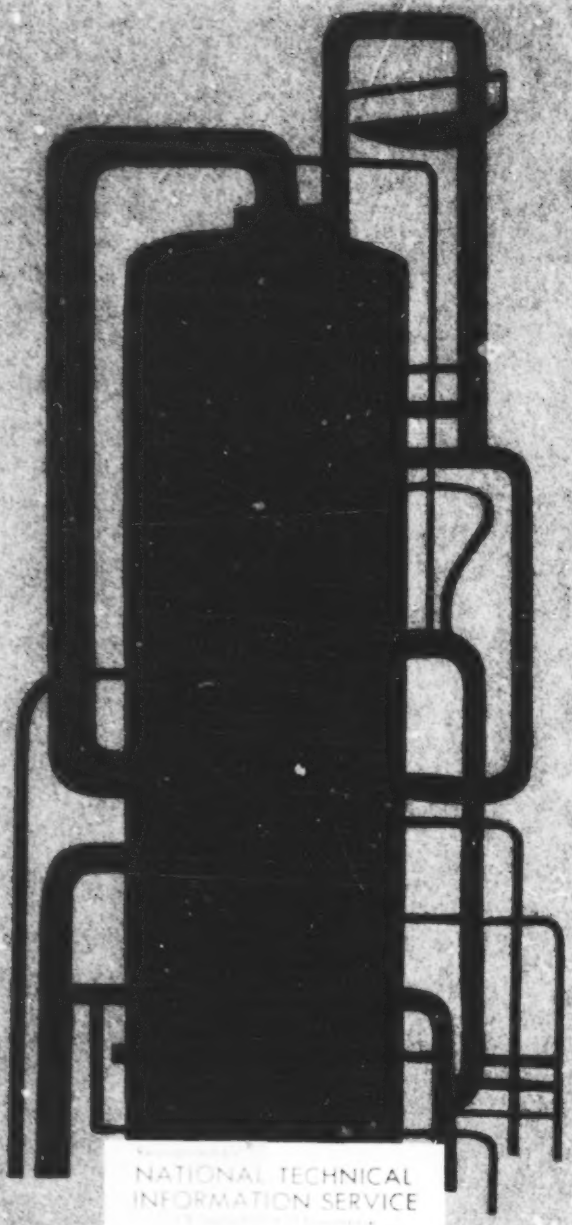

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REPORT NUMBER 3

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by
Bernard J. Steigerwald

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JOINT DISTRICT, FEDERAL AND STATE PROJECT
FOR THE EVALUATION OF REFINERY EMISSIONS

Hydrocarbon Leakage from Pressure Relief Valves

IN BRIEF:

One phase of the Joint District, Federal and State Project for the Evaluation of Refinery Emissions was the study of hydrocarbon leakage from pressure relief valves. This report details the techniques and conclusions of the study.

The seven major refineries in the Los Angeles area, processing about 90 per cent of the local crude throughput, reported a total of 1100 relief valves on operational units and 350 relief valves on pressure storage vessels.

Field tests made on 460 valves indicated an average leak for valves on operational units of 2.9 pounds per day per valve while pressure storage valves leaked an average of 0.4 pounds per day per valve. These figures were based on 20 measured large leaks and loss estimates of 77 small leaks. The sampling technique for gaseous leaks usually involved an initial qualitative test with a combustible gas indicator followed by a direct volumetric measurement when large leaks were encountered. Cursory inspection of valves on liquid lines indicated that losses from this source were of minor importance and no rigorous testing program was attempted on liquid leaks.

The total hydrocarbon leakage, calculated by projecting the field test data to the reported number of valves in each group, was found to be 3500 pounds per day. This figure includes only continual leakage through the valve seat. Emissions due to relief valve blowoff were not considered in this study.

Hydrocarbon Leakage from Pressure Relief Valves

INTRODUCTION

In August, 1955, the Los Angeles County Air Pollution Control District, the California State Department of Public Health and the U. S. Public Health Service jointly inaugurated a program to evaluate atmospheric emissions from oil refineries in Los Angeles County. The Western Oil and Gas Association participates in the project as the industrial representative.

Hydrocarbon leakage from pressure relief valves, being of undertermined magnitude, was one of the items listed for a complete testing program. Corrosion and failure of valves to reseat properly after blowoff, coupled with maintenance and observational difficulties caused by the inaccessible nature of most pressure relief installations could allow substantial leakage before repair. Only losses through continual valve leakage were considered. Emissions due to the valve blowoffs were not included in this study.

RELIEF VALVE CENSUS

In order to design a valid sampling program, data were obtained concerning the number and distribution of relief valves in the county. Questionnaires (see Appendix) were distributed through the Western Oil and Gas Association to the seven major oil refineries in Los Angeles County. These seven companies account for about 90 per cent of the local refinery capacity. Visits to many of the smaller refineries and observations of both number of valves and type of operations indicated a minor contribution to relief valve leakage from this source.

Relief Valve Questionnaire

In designing the survey questionnaire, it was necessary to consider the factors influencing leakage from relief valves. These include the known recorded parameters such as pressure, product, valve type and size, and other less obvious factors including blowoff frequency and ease of maintenance. An attempt was made to incorporate these factors into the questionnaire by requesting valve data as described below:

Refinery Process Units. The classification by refinery process units was included to help isolate such leakage variables as ease of maintenance, blowoff frequency, pressure and product. The specified refinery breakdown followed in general the standard nomenclature initiated in the valve and flange survey of the Joint Project. The major classifications were:

Crude Processing
Thermal Cracking
Catalytic Cracking
Catalytic Reforming
Light Hydrocarbon Processing
Gas Processing and Treating
Light Product Treating
Pressure Storage, Blending and Shipping
Other

The questionnaire further defined each classification for greater clarity.

Vented Product. Differentiation between gaseous and liquid products when at atmospheric pressure and a standard temperature ($60^{o}F.$) was requested. It was assumed that each operational vessel would, regardless of product, have sufficient vapor space near the relief valve to leak only a light gaseous product. Lack of condensation of leaking vapors upon cooling in the test lines supported this assumption. Since it follows that only valves on liquid lines could have liquid leaks, these were listed separately.

Valve Type. As a further indication of maintenance ease, the questionnaire requested the breakdown of relief valves into single and dual types. Dual type relief valves were defined as pressure relief installations which allow valve removal while the unit is in operation, usually accomplished by having two pressure relief valves, fitted with interdependent manual valves. The relief valves can then operate alternately from the same vessel stem. A single relief valve is the more typical installation. Figure 1 shows an installation of three single valves.

Destination of Vented Product. Since this study is limited to the hydrocarbon leakage from relief valves alone, only those valves venting to the atmosphere were considered. Emissions from blowdown stacks, flares, and other vapor recovery system components will be considered in future Joint Project studies.

The census questionnaire used in this study was considered to be a reasonable compromise, allowing reporting ease while supplying sufficiently detailed information for data extrapolation.

Census Results

The results of the relief valve census are presented in Table IV (see Appendix). It was concluded that due to the inaccessibility and limited sampling opportunities for valves in most operational groups, it was both desirable and feasible to consolidate the census data into two process unit classes—operational units and pressure storage vessels. A review of the parameters involved in the design of the questionnaire confirms the validity of this step. The blowoff frequency, pressure variability, product, and ease of maintenance all remained grouped in this simpler classification. The small number of field observations of dual relief valves also warranted consolidation of valve type into a single group for operational unit relief valves. Table I summarizes the refinery census in the form used in data extrapolation procedures. A total of 1465 valves were reported exclusive of those on liquid lines and those venting to vapor recovery systems. Of these 1465 valves, 1113 are on operational units and 352 relieve pressure storage vessels.

TABLE I

Refinery Relief Valve Census - Consolidated Results

Unit	Type Valves	Valves Venting to Atmos.		Valves Venting to Vapor Recovery System
		Liquid Lines	Gaseous	
Operational	All	400	1113	1589
Pressure Storage	Single		237	
	Dual		115	
	Total	290	352	179
Summation		690	1465	1768

TESTING PROCEDURES

Due to the inaccessibility and variable nature of relief valve installations, no standard testing procedure will be universally applicable. The procedures used in this study and presented here will be effective for a large majority of situations. Should a sampling program demand tests on specific valves, some adaptations at the valve site may be necessary.

For gas leaks a qualitative test of the atmosphere in the valve horn was first made with the combustible gas indicator (Fig. 2). If this yielded positive results, the top of the valve horn was encased in an airtight polyethylene shroud vented through a meter for direct volumetric measurement of hydrocarbon vapor loss (Fig. 3). If the top of the horn was inaccessible and other secondary horn openings such as steam purge lines or water drains existed, a continuous metered sample was drawn from the valve (Fig. 4). A combustible gas indicator was used to determine the concentration of hydrocarbons in this gas stream. The amount of leakage was calculated from this information.

No method was developed for testing liquid leaks. Visual inspection of approximately 100 valves on liquid lines revealed no leakage and no staining to indicate any past leaks. It was concluded that a formal testing program for liquid leaks was not justified.

Direct Test Method

The following procedure is considered more direct, simple and accurate and should be used whenever possible (Figs. 3, 5):

Testing for Leaks. To find those valves that are leaking, a probe was dropped deep into the valve horn and a sample drawn into a combustible gas indicator. If no combustible gas was detected, the valve was considered tight and not leaking. When the concentration of hydrocarbons deep in the horn was less than 100 per cent of the lower explosive limit (L. E. L.) the valve was considered to have a small leak. If a reading greater than 100 per cent of the L. E. L. was obtained, further steps were taken to determine the magnitude of the leak before a quantitative test was attempted.

When a small drain hole was available at the base of the horn, the presence of a visibly obvious stream of hydrocarbon vapor from the drain hole indicated a large leak and was sufficient evidence to warrant a complete test. When no drain hole was present, the probe of the combustible gas indicator was placed near the top of the horn and the hydrocarbon concentration noted. A value greater than 100 per cent of the L. E. L. with the probe in this

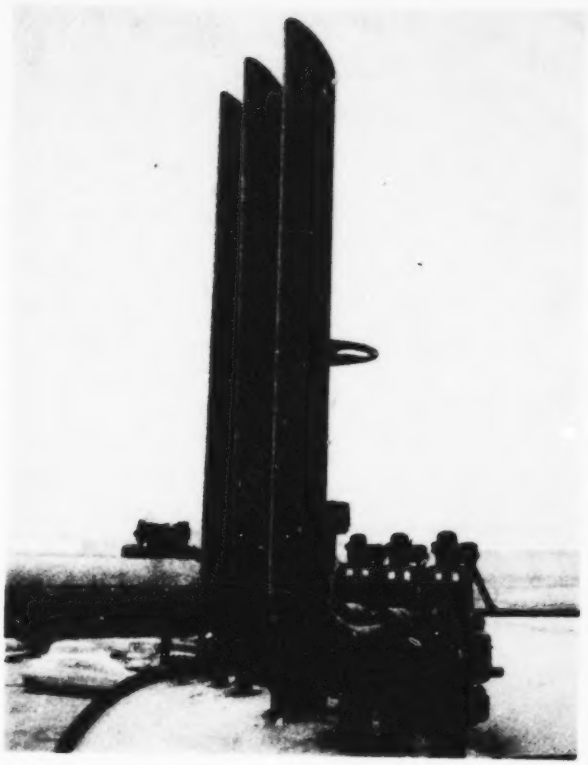

Figure 1. Typical pressure relief installation showing three single type relief valves.

Figure 2. Testing for hydrocarbons in relief valve horn using M.S.A. Explosimeter.

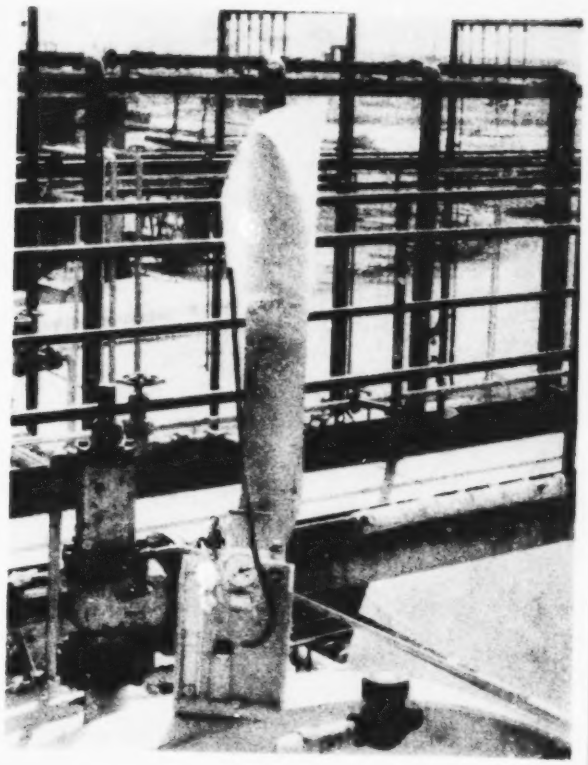

Figure 3. Direct test method for measuring leak rate from relief valves. A polyethylene shroud covers the horn outlet, and a dry gas meter measures the volume of gas escaping.

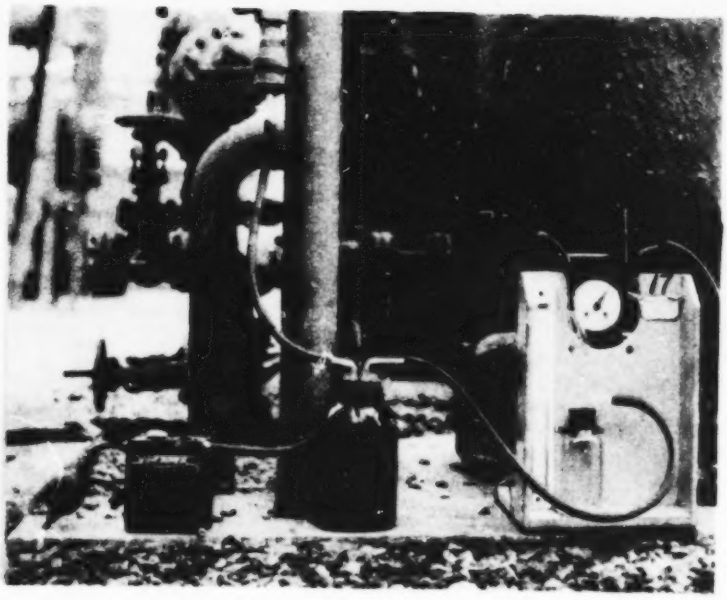

Figure 4. Indirect test method for measuring leaks from inaccessible relief valves. Air, and gas escaping from valve, are drawn into the surge bottle. The flow rate is measured with a dry gas meter and the gas stream is analyzed for hydrocarbons with an M.S.A. Explosimeter.

position indicated a large leak. The rate of inflation of a polyethylene sack held over the top of the horn also gave an indication of the size of the leak.

In this study, any leak less than 0.5 cubic feet per hour (CFH) was considered a small leak, and although noted for leakincidence figures, no attempt was made to measure the loss. It was found that some experience, combined with the initial sampling techniques described above allowed reasonably accurate differentiation between large and small leaks.

Measurement of Leak Rate. The following procedure was used to determine the leak rate from accessible valves having probable large leaks. A polyethylene bag was selected having a diameter slightly larger than that of the horn and with sufficient depth to cover the diagonal cut at the top of the horn. A corner of the bag was cut off and clean semi-rigid plastic tubing inserted into the opening. The tubing should extend at least six to eight inches into the bag to assure a free tube inlet during the test. Masking tape and careful folding of the bag around the tube were usually sufficient to assure an air-tight seal at this junction. The strength of the semi-rigid tubing allowed a very firm application of the tape. Narrow tape, under one-half inch, was found best for this purpose.

The bag prepared in this manner was slipped over the top of the horn. Before a seal was attempted, it was usually necessary to clean the horn in the vicinity of the seal. A dry rag was used for this purpose, although a wire brush or a solvent could be used. The polyethylene sack should be pulled down over the horn as far as possible to minimize the surging caused by action of the wind on the inflated sack. Glyptal cement was then spread on the horn in a thin uniform ring at the seal junction. Other sealing agents were tried with some success in similar studies, but Glyptal was found to have a good drying rate for this type of work. The excess bag perimeter was taken up in one large fold and the application of wide masking tape completed the seal. The use of wide tape allows contact with both the horn and shroud and adds to the effectiveness of the seal.

The entire horn installation was then checked for secondary openings. Any steam purge lines were valved off and smaller openings such as drain holes plugged. Any flanges between the valve seat and the top of the horn were also inspected, sealed if necessary and checked with the combustible gas indicator throughout the test. The adequacy of the entire test set-up was evaluated by gently blowing back into the tube and noting the rate and stability of the sack inflation. Failure of the shroud to inflate rapidly or maintain pressure once inflated indicated a faulty seal or the presence of additional secondary openings.

A length of rubber tubing was connected to the tubing protruding from the bag to conduct the leaking gas to the flow meter. After an initial period of pressure build-up, steady flow conditions were reached and the leak rate noted.

Indirect Test Method for Inaccessible Valves Having Accessible Secondary Horn Openings

When the valve to be tested has an inaccessible horn with an available secondary opening such as drain hole or steam purge line, the following procedure may be used to determine the presence and magnitude of hydrocarbon leaks. Since more time is involved and more elaborate equipment is necessary than with the direct volumetric techniques described earlier, this method should be used only when the direct method is not applicable. Further, it does not allow an initial differentiation between large and small leaks. In many cases very large leaks cannot be quantitatively determined in the field, and a grab sample must be taken for laboratory hydrocarbon analysis. Infrared techniques were used in this study.

The equipment was arranged as shown in Figure 6. An adjustable rubber sleeve or a single-hole stopper was usually necessary to adapt from the sampling outlet to normal size tubing. A surge bottle was inserted in the line to allow some flow integration and to provide a sampling point for the combustible gas indicator or the removal of grab samples. A gas flow meter and source of vacuum completed the equipment set-up.

The valve horn or steam line was purged at a rapid rate until it was felt that all of the stagnant gas in the system had been removed. A check was made to assure that no large openings or manifold systems caused short circuiting, since the air being tested must pass over or near the valve itself for this technique to be effective. A combustible gas indicator was used to test for hydrocarbons in the air stream. If hydrocarbons were present, the flow rate was allowed to steady and was noted along with the reading on the combustible gas indicator. A five-minute period was usually sufficient to assure steady flow conditions. The flow was usually varied until a dilution was obtained which allowed a mid-range reading on the combustible gas indicator.

Many leaks giving initial positive results can be immediately recorded as a small leak by noting the product of the approximate combustible gas indicator reading in per cent and the air flow rate in CFM. For example, a hydrocarbon leak of 0.5 CFH, assuming a lower explosion limit of two per cent (propane-butane range) will have a product greater than 40 (see Data Evaluation--Calculations). Any test giving a product less than this can be considered a small leak and no further manipulations need be made.

With very large leaks, flow limitations would not allow sufficient dilution of the hydrocarbons to a value below the L. E. L. When this occurred, a grab sample was taken after steady flow conditions were reached. The flow rate at this time was also noted. The sample was then analyzed for hydrocarbon concentration [1] and the leak rate computed in the normal manner. The use of an accurate dilution valve on the combustible gas indicator will greatly increase the upper limit of the usual method and reduce the number of grab samples required. However, the set-up pictured in Figures 4 and 6 creates a vacuum in the sampling bottle, causing air to be drawn into both the sampling bottle and the combustible gas indicator when the dilution valve is opened. A reading of zero always results and normal dilution valves cannot be used. Where many large leaks will be encountered, the use of a neutral pressure sampling station and a series of dilution valves is advisable.

Apparatus and Materials

The following equipment was used:

Combustible Gas Indicator
Vacuum Pump (for indirect method only)
Gas Meter
Surge Bottle (for indirect method only)
Grab Sample Bottles (for indirect method only)
Polyethylene Bags (for direct method only)
Sealing Materials (for direct method only)
Tubing and Adapters

Combustible Gas Indicator. Both a Mine Safety Appliance (M. S. A.) Model-2 Explosimeter and a Davis Vapotester Model M-6 were used initially in this study. It was found that the M. S. A. instrument, being lighter, smaller, more portable and requiring less adjustment, was better suited for the type of field work encountered in the testing of pressure relief valves.

Vacuum Pump. A simple compressed air ejector was used in this study, but any explosion-proof electric or air-driven pump is adequate. A free flow capacity of at least five cubic feet per minute (CFM) should be provided.

(1) Mader, et. al., "Determination of Small Amounts of Hydrocarbons in the Atmosphere", Anal. Chem. 24, pg. 1899 (1952)

Gas Flowmeter. A wet or dry gas meter capable of measuring air flows up to five CFM and equipped with a handle or mounted on a portable rig is suitable for most testing. A Sprague dry gas meter Model 1A was used in this study. A rotameter or other compact flow measuring device should be provided to facilitate tests on towers or other installations which require much climbing.

Polyethylene Bags. A wide range of sizes is necessary to provide complete coverage. Relief valve horns vary from two to twelve inches in diameter. The maximum bag depth necessary to cover the diagonal top cut of valve horns is 18 inches.

Sealing Materials. As outlined in the procedure section, these consist of Glyptal No. 1286 cement, masking tape of various widths and a wire brush or solvent for cleaning the horn at the seal junction.

Tubing. An 18-inch length of semi-rigid plastic tubing is necessary to allow a tight seal into the bag. Tygon or Saran tubing of 1/4" I.D. was used for this purpose. Rubber tubing of 1/4" I.D. was used elsewhere in the study.

SAMPLING PROGRAM

Scope of Valve Testing Program

Valves Venting a Gaseous Product. The initial testing program, based on the factors influencing the design of the refinery relief valve questionnaire, called for sampling a substantial portion of the valves reported for each refinery unit. The test results for each unit originally were to be expanded by the number of reported valves in each group and the results totaled for a loss figure. Data obtained from testing dual and single type valves were also to be projected separately in each class.

From the initial field tests it was apparent that such a detailed sampling program was impractical. The inaccessibility of relief valves on most operational units and the limited testing opportunities available tended to stultify the original data extrapolation program. It was decided to consolidate the eight original process units into two groups. These were operational units and pressure storage vessels. Initial field observations also indicated the feasibility of testing all accessible valves in Los Angeles County. This was about 90 per cent accomplished and eliminated uncertainties concerning the necessary sample size for each group.

Table II shows the number and percentages of valves tested for each class. It should be noted that the separation of single and dual type valves was maintained for pressure storage vessels. One hundred sixty-five operational and 253 pressure storage valves were checked. This is approximately 29 per cent of the total number and about 90 per cent of the accessible valves handling gaseous hydrocarbons. It required 16 days employing a crew of two to complete the testing in the 14 refineries visited, including all the major and seven minor companies in the County.

Relief Valves on Liquid Lines. Since it was shown earlier that a liquid leak could only occur from valves on liquid lines, these were listed separately for a possible field testing program. Visual inspection of approximately 100 valves on liquid lines revealed no liquid leakage and no staining to indicate any past leaks. These observations, a consideration of the low average vapor pressure of the product, and the ease with which leaks can be observed and repaired, led to the conclusion that relief valves on liquid lines make a minor contribution to total loss figures and a formal testing program was considered unnecessary.

Relief Valves Venting to Vapor Recovery Systems. Valves venting to vapor recovery systems, although polled in the relief valve census, were not included in this study. The hydrocarbon emissions from vapor recovery systems, if any, will be considered by future Joint Project studies.

Results of Field Tests

The results of the field tests are shown in Table II , Leakage from relief valves on operational units averaged 2.9 pounds per day per valve, while those on pressure storage vessels averaged 0.4 pounds per day per valve. It should be noted that of the total 460 pounds per day measured leakage from operational unit valves, 308 pounds per day were from two relief valves on the same unit. The largest leak from a pressure storage vessel valve amounted to 19 pounds per day.

Dual type relief valves on pressure storage vessels had both a higher leak incidence and larger average leaks than single type valves in similar service. Sufficient field observations could not be taken on operational unit relief valves to compare leakage between dual and single type valves and these are listed as a single group.

TABLE II

Results of Field Tests

Relief Valves Venting Gases to Atmosphere

Valve Group	Valves Tested		Number of Leaks		Measured Loss Large Leaks Lbs./Day
	Number	Per cent of Reported Valves	Small	Large >0.5 CFH	
Operational Units	165	15	22	8	460
Pressure Storage					
Single Type	174	73	29	4	30
Dual Type	79	69	26	8	75
	418	29	77	20	565

DATA EVALUATION

Results

The total hydrocarbon leakage from pressure relief valves in Los Angeles County is estimated to be under two tons per day. This was calculated by summing the projection of field data for the three valve groups as shown in Table III . No quantitative loss data is available for small leaks. They were assigned an average leak rate of 0.9 pounds per day. This is 0.25 cubic feet per hour (C.F.H.) or one-half the value defined as the maximum small leak using the molecular weight of butane for calculation purposes.

For large leaks the field measurements were recorded in cubic feet per hour at normal atmospheric temperatures and pressures. The calculation to a weight basis for gross pollution figures depends directly on the molecular weight of the vented gas. With valves on pressure storage vessels this could be accurately estimated, but the loss from operational vessels presented some difficulty. As discussed earlier, it was assumed that all vessels contained enough vapor space near the relief installation to vent only a gaseous product. It was also concluded that the products handled in process units contained enough high vapor pressure components substantially to fill the vapor space with these light products. Since no obvious vapor condensation occurred upon cooling in the test lines, it was concluded that the greater portion of the hydrocarbons escaping must be pentane or lighter. In most cases the estimate of the unit operator or refinery air pollution representative concerning the nature of the product was used. Where a range of products was indicated, an average molecular weight, never exceeding that of pentane, was used in calculations.

The results detailed below do not include any loss from relief valves on liquid lines. As stated earlier, observations indicated that the loss from these is of minor importance.

TABLE III

Summary of Data and Calculations

(1) Valve Group	(2) Number of Valves Reported	(3) Number of Valves Tested	(4) Hydrocarbon Loss-Lbs./Day Small Leaks	(5) Large Leaks	(6) Total	(7) Loss per Tested Valve Lbs/Day (6) ÷ (3)	(8) Total Loss Lbs/Day (2) x (7)
Operational Units	1113	165	20	460	480	2.90	3230
Pressure Storage:							
Single	237	174	26	30	56	0.32	80
Dual	115	79	23	75	98	1.24	140
							3450

Statistical Review of Results. A frequency distribution of measured leaks produced a curve highly skewed toward the smaller leaks (Appendix). This is illustrated by comparing the mean measured leak rate of 28 pounds per day per valve and the median of 10 pounds per day per valve. This type of distribution seems reasonable considering the factors influencing leak rates. Large leaks would occur less frequently and would be quickly observed and repaired. The frequency curve produced did not lend itself to normal statistical analysis and it was felt that personnel limitations and the magnitude of the total loss did not warrant attempts at more advanced statistical techniques. Statisticians did agree that testing 400 of the 1500 relief valves in the County should allow safe projection of the test data. However, they could not readily estimate the reproducibility nor comment on the degree of confidence the data inspire.

Calculations

Weight Rate of Flow (direct test procedure)

$$\text{Lbs/Day} = \text{SCFH} \times 24 \frac{\text{hr.}}{\text{day}} \times \frac{\text{mol. wt.}}{\text{lb. mol. gas vol.}}$$

$$\text{Lbs/Day} = 0.063 \times \text{SCFH} \times \text{mol. wt.}$$

SCFH - Standard cubic feet per hour (60°F. and 29.92 inches of mercury) - since the field work was done in December and January, with ambient temperatures generally near 60°F., no temperature corrections were made.

mol. wt. - molecular of vented product in lb/lb - mol.

lb. mol. gas vol. = 379 cu. ft./lb. mol. at 60°F. and 29.92 inches of mercury.

Weight Rate of Flow (indirect test procedure)

$$\text{lb./day} = \text{exhaust rate (SCFM)} \times A \times \frac{\text{L.E.L. (\%)}}{100} \times 1440 \frac{\text{min.}}{\text{day}} \times \frac{\text{mol. wt.}}{\text{lb. mol. gas vol.}}$$

SCFM - Standard cubic feet per minute (60°F. and 29.92 inches of mercury).

A - Combustible gas indicator reading (no dilution) in fraction of lower explosive limit (L.E.L.)

L.E.L. (%) - Lower explosive limit; hydrocarbon concentration in per cent by volume (available in most chemical handbooks). The values used in this study are given below:(2)

propane	2.3
n-butane	1.9
n-pentane	1.4

Discussion

Losses from relief valves in individual refineries often showed leakage rates far different from the overall average. Comparing figures for valves on operational vessels, the average for all refineries was 2.9 pounds per day per valve, while average losses from specific refineries varied from zero to 9.1 pounds per day per valve. This indicates that under diverse conditions of operation and maintenance, leakage could vary greatly from the two tons per day reported in this study.

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(2) Petroleum Processing, March, 1957 (pg. 139)

While it is believed that the loss figures presented here are substantially correct and give a true picture of hydrocarbon leakage from relief valves in Los Angeles County, a number of assumptions were made and other sources of possible error exist. These are reviewed and evaluated below.

Testing Program. Since the inaccessible nature of operational unit relief valve installations did not allow a high degree of planned testing, the sampling of process units was unevenly distributed in both type of unit and number of refineries checked. For example, certain processes such as alkylation and crude topping were more accessible and possibly had a disproportionate influence on the loss figures. Because safety codes at many refineries prohibit tests on some operational vessels, average loss figures on operational unit valves strongly reflect conditions at only three of the major refineries in Los Angeles County.

Vented Product. The assumption was made that the molecular weight of the vented product must be below that of pentane. It is true that some heavier hydrocarbons would exist as vapor at normal temperatures and would increase the average molecular weight and loss figures. For example, a gas stream saturated with n-octane would contain 1.3 per cent octane at normal temperatures. Lack of obvious vapor condensation indicated that saturation probably never occurred and no attempt was made to adjust for these heavier components in the direct volumetric test procedure. However, when using the indirect test procedure where measurements are made of low hydrocarbon concentrations as dilute as 0.2 per cent in air, a much better estimate of the vented product must be made.

CONCLUSIONS

1. Hydrocarbon leakage from pressure relief valves in oil refineries in Los Angeles County amounts to about two tons per day.

2. Relief valves on operational units have a slightly lower leak incidence, but a much higher average leak rate than do valves on pressure storage vessels.

3. Dual type relief valves on pressure storage vessels had a greater leak incidence and larger average leak rate than single type valves in similar service. Internal or locomotive type valves appear to have a much lower leak incidence than either of the above types. Only one small leak was discovered in checking 56 internal type valves, all on storage vessels.

4. The testing procedures used in this study and detailed in this report provide a realistic, practical way to test pressure relief valves for gaseous hydrocarbon leakage.

APPENDIX

AIR POLLUTION CONTROL DISTRICT - COUNTY OF LOS ANGELES
434 South San Pedro Street, Los Angeles 13, California

Table IV

REFINERY RELIEF VALVE CENSUS - COMPLETE RESULTS

Unit	NUMBER OF VALVES			
	Venting Vapor to Atmosphere		On Liquid Lines Venting to Atmosphere or Drain	Total Valves Venting to Recovery System
	Single Type	Dual Type		
Crude Processing	70	21	87	202
Thermal Cracking	91	40	33	174
Catalytic Cracking	132	57	61	168
Catalytic Reforming	33	12	0	182
Light Hydrocarbon Processing	247	111	3	493
Gas Processing & Treating	80	38	14	99
Light Product Treating	17	13	61	187
Storage Blending & Shipping (pressure)	237	115	290	179
Other	141	10	141	84
TOTAL	1048	417	690	1768

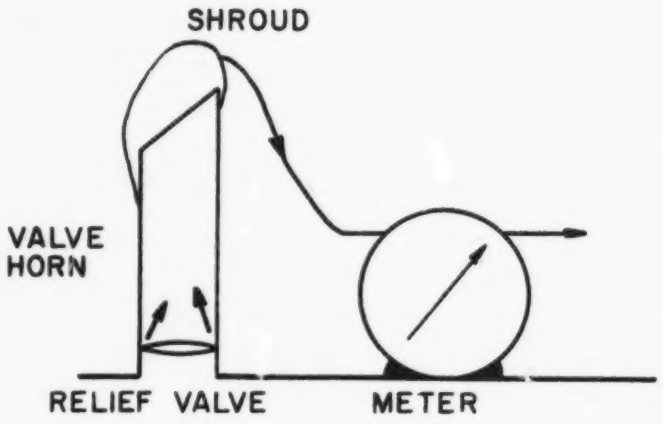


FIG. 5 TEST SETUP — DIRECT SAMPLING METHOD

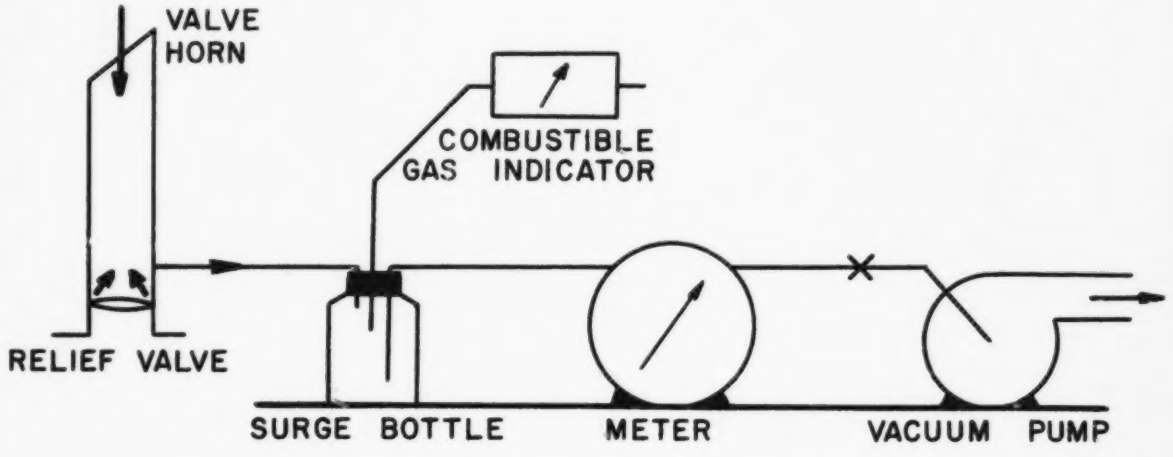
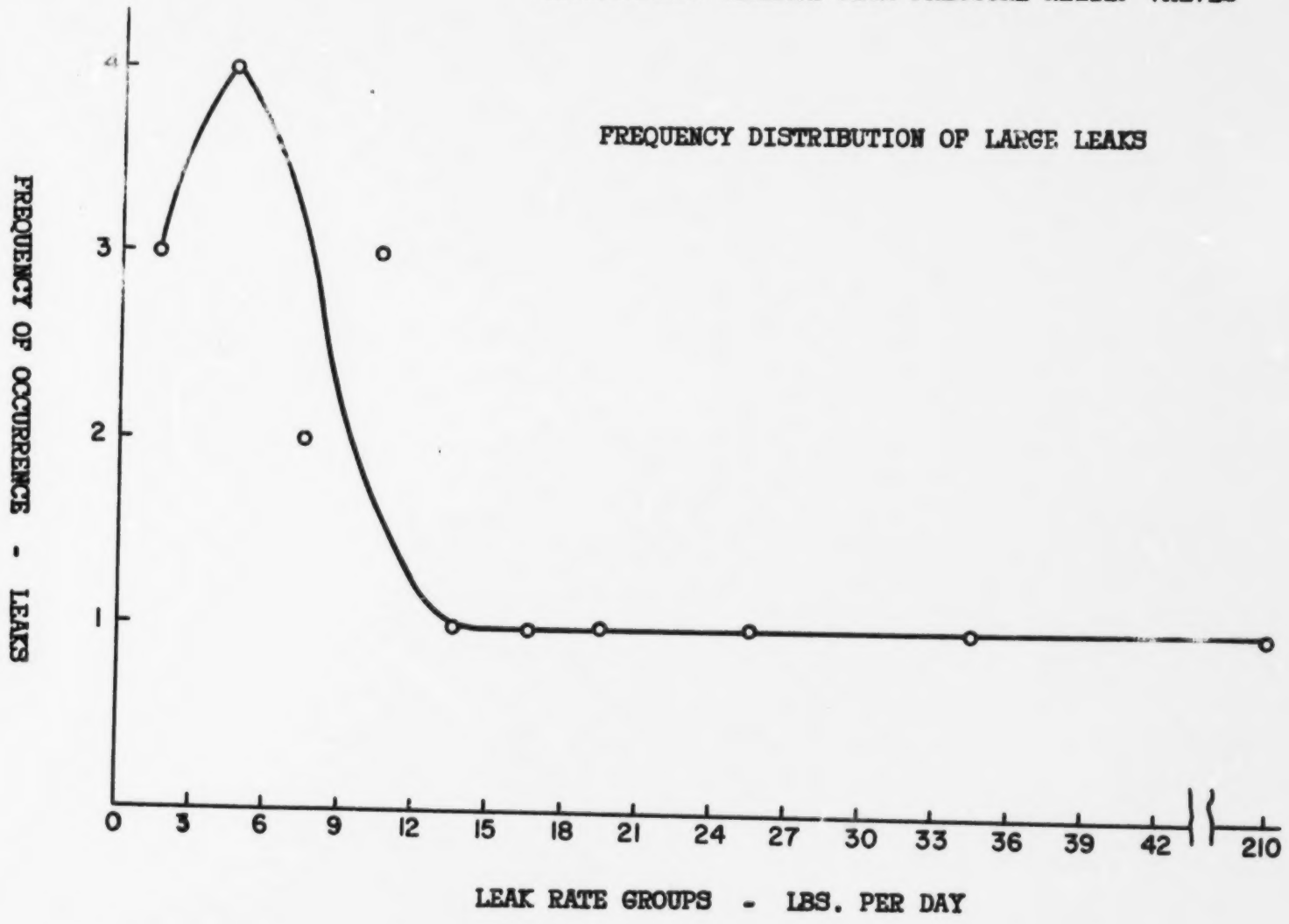


FIG. 6 TEST SETUP — INDIRECT SAMPLING METHOD

HYDROCARBON LEAKAGE FROM PRESSURE RELIEF VALVES

FREQUENCY DISTRIBUTION OF LARGE LEAKS



AIR POLLUTION CONTROL DISTRICT - COUNTY OF LOS ANGELES
434 South San Pedro Street, Los Angeles 13, California

RELIEF VALVE CENSUS

Company: _____ Date: _____

Address: _____

Unit	No. of Relief Valves Venting Directly to Atmosphere			No. of Relief Valves Manifolded to Recovery Systems	Ultimate Disposal of Hydrocarbon Vented to Recovery System
	Valves Not on Liquid Lines		Total on Liquid Lines		
	Single Type	Dual Type*			
Crude Processing (Vac. dist., straight run, asphalt, etc.)					
Thermal Cracking (visbreaking, coking, thermal reforming, etc.)					
Catalytic Cracking					
Catalytic Reforming					
Light Hydrocarbon Processing (polymerization, alkylation, LPG, isomerization, etc.)					
Gas Processing and Treating (gas concentration, gas absorption, etc.)					
Light Product Treating (doctor, hydrotreating, etc.)					
Storage, Blending and Shipping (pressure storage only)					
Other (specify)					

*Dual-valve relief equipment includes only those installations venting through two interdependent valves which can operate alternately from the same vessel stem.